

SECTION 5- NECK ASSEMBLY

5.1 Neck Assembly Description and Features

The goal for the neck design used in the THOR dummy was to develop a multidirectional neck which responds in a human-like manner independent of the direction of impact. This goal has become increasingly important in the past several years with the interest in offset, rear and roll over crash testing for automotive safety engineering. The THOR neck assembly accomplishes this goal through the use of compression springs located in the fore and aft regions of the skull to simulate the effects of musculature and correct head motions in the frontal flexion and extension directions. In addition, rubber soft stops are attached at the base of the neck to achieve the desired bending characteristics in both fore and aft motion. The neck assembly is made from a series of aluminum disks and rubber pucks which are bonded together using an epoxy resin system. The rubber pucks are elliptically shaped to provide the desired lateral bending response for the neck assembly.

The instrumentation for the new neck assembly includes: a pair of miniature load cells to measure the compression at the fore and aft spring locations; six component load cells at the top (Denton: Model B-3454) and base (Denton: Model 2357) of the neck to measure the forces and moments developed at these locations; and a rotary potentiometer is used at the condyle pin to measure the relative rotation between the head and neck. **Figure 5.1** shows a drawing of the THOR neck assembly.

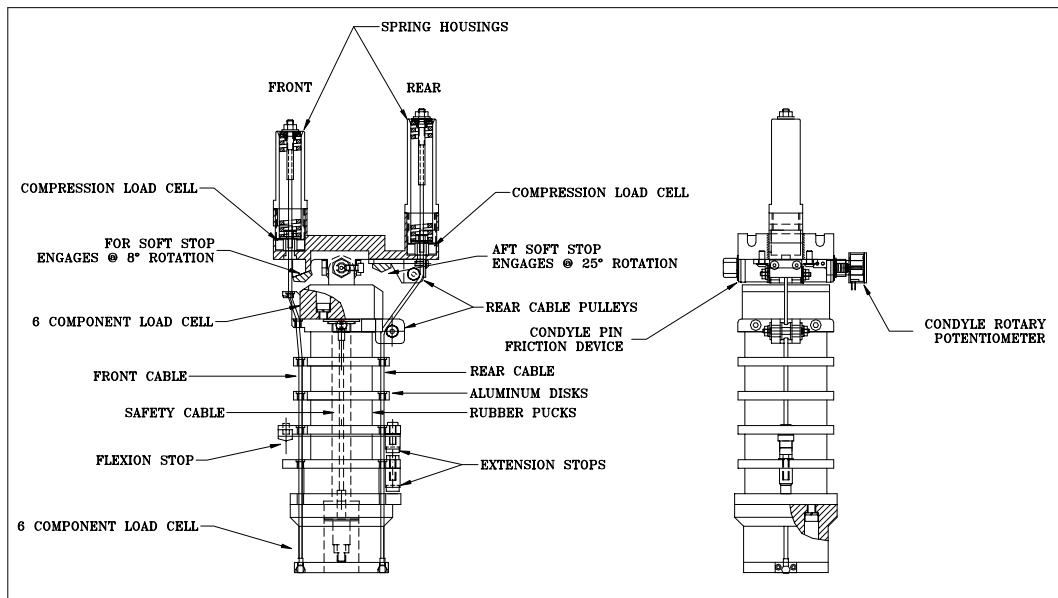


Figure 5.1- Neck assembly

5.2 Assembling the Neck

5.2.1 Parts List

The parts list and quantities for all parts for the neck assembly is listed in Appendix I - Bill of Materials under the Neck subsection. Refer to drawing T1NKM000 in the THOR drawing set for a detailed mechanical assembly drawing. **Figure 5.2** is a drawing of the exploded neck assembly and hardware.

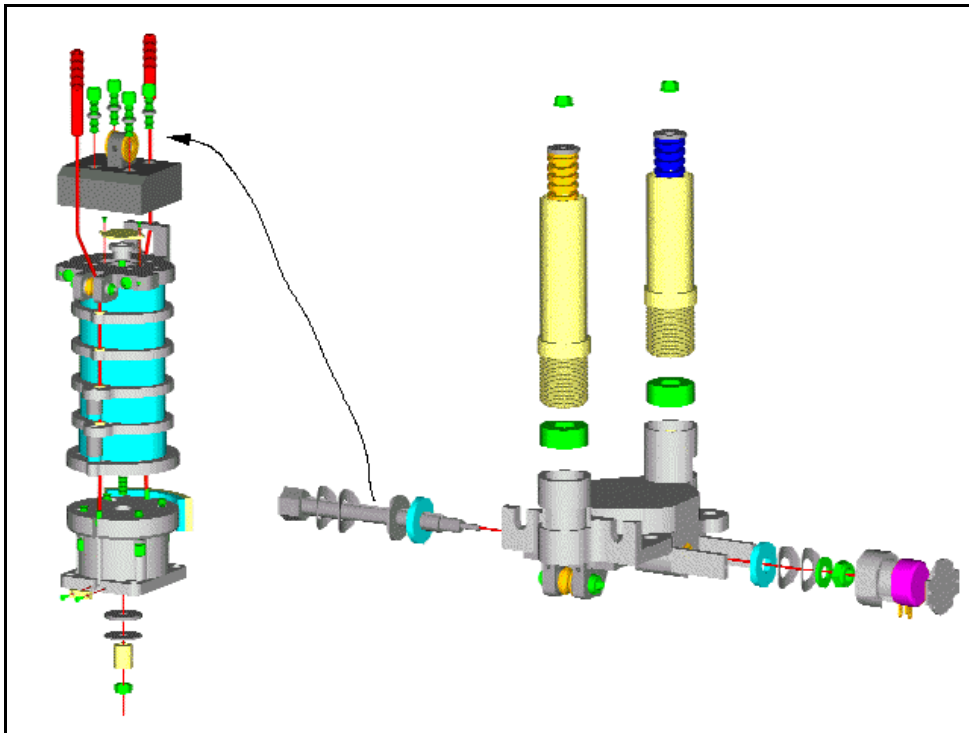


Figure 5.2- Exploded neck assembly

5.2.2 Assembly of Neck Components

The following procedure is a step-by-step description of the assembly procedure for the neck components. The numbers provided in () refer to a specific drawing / part number of each particular part. The numbers noted in { } after the bolt size indicate the size of the hex wrench required to perform that step of the assembly. All bolts should be tightened to the torque specifications provided in Section 2.1.3.

1. Identify the front of the Neck Bonded Assembly (T1NKM100) by looking at the top plate. The plate has a machined bracket which stands up and bends toward the front. Pass the Neck Front Cable Assembly (T1NKM122) through the holes in the front of the neck plates, starting at the top, ball end of the cable first. Perform the same procedure with the Neck Rear Cable Assembly (T1NKM117) on the holes in the rear of the neck plates.
2. Assemble the Cable Guide Halves (T1NKM118) at the ten locations shown in

Figure 5.3. Two halves are positioned in each hole that the cable passes through and are pressed into the hole around the cable.

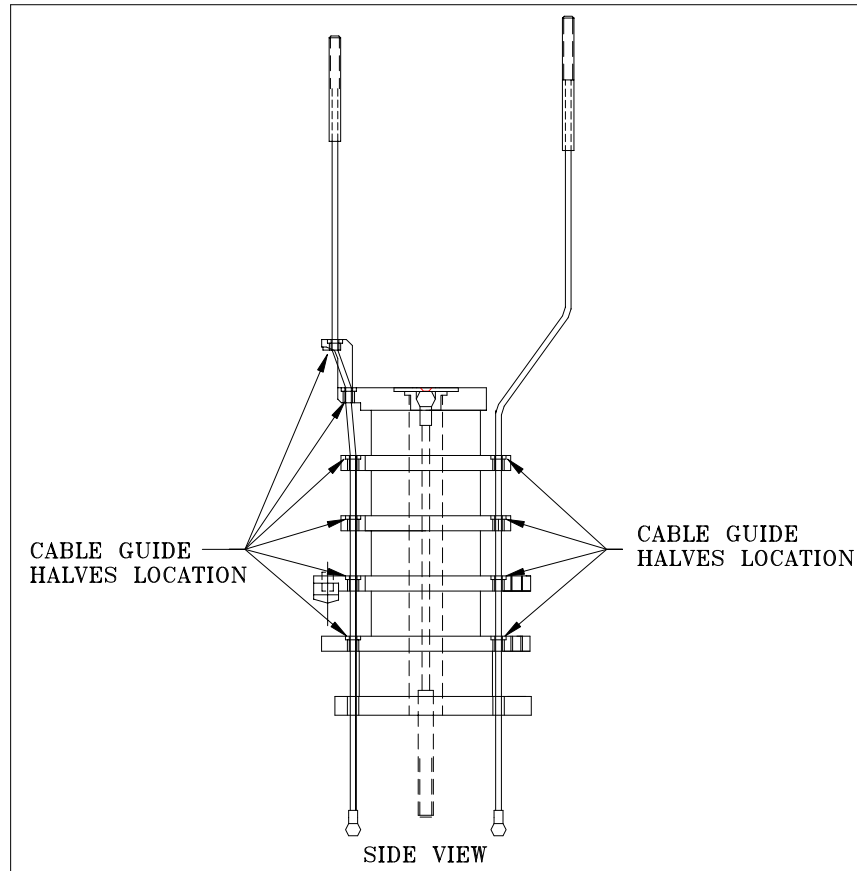


Figure 5.3- Cable guide locations

3. Identify the front of the Lower Neck Load Cell (T1INM320) by looking at the four main mounting holes. The holes are spaced closest together on the front side of the load cell. (Note: The instrumentation wires exit at the rear of the load cell.) Pass the front and rear cable ball ends through the cable mounting holes in the front and rear of the lower neck load cell respectively. The cables should pass through the load cell top plate and out the slots in the side as shown in **Figure 5.4**.

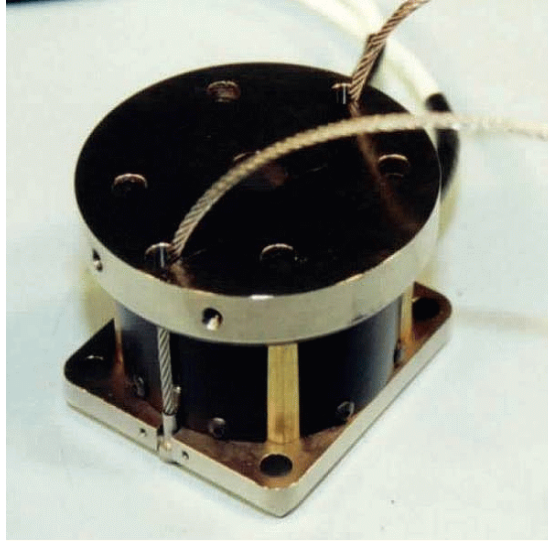


Figure 5.4- Cables in lower neck load cell

4. Attach the Lower Neck Load Cell (T1INM320) to the bottom plate of the Neck Bonded Assembly (T1NKM100) using four 1/4-20 x 5/8" SHCS {3/16} with 1/4" split lock washers.
5. Pass the front and rear neck cables through the slot in the front and back of the lower neck load cell bottom plate and pull the ball ends of the cables up into the cable retaining holes on the bottom of the load cell as shown in **Figure 5.5**.

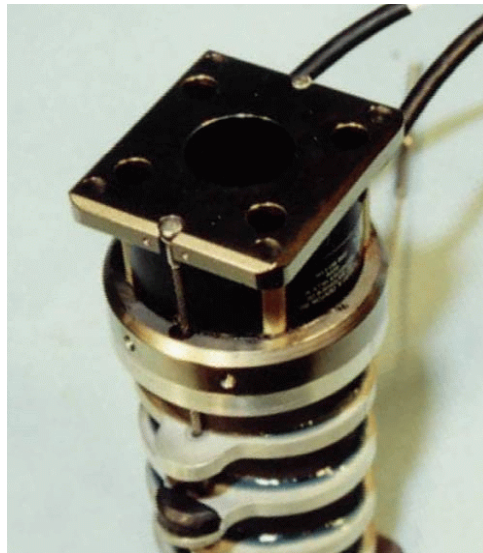


Figure 5.5- Proper placement of cables in lower neck load cell

6. Place the Lower Neck Load Cell Bumper (T1NKM025) against the front of the Lower Neck Load Cell. Position the Lower Neck Load Cell Bumper Cover (T1NKM024) over the bumper and secure both to the load cell using two #10-32 x 3/4" BHSCS {1/8"} as shown in **Figure 5.6**.

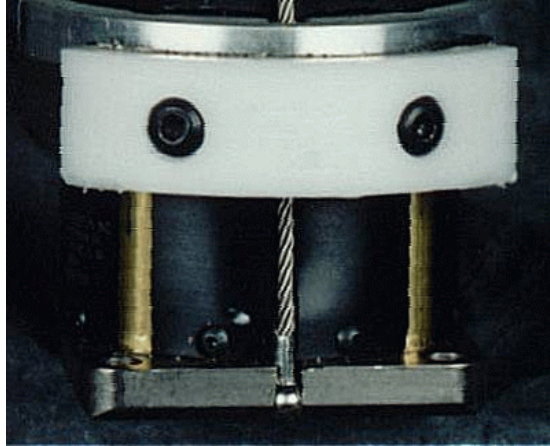


Figure 5.6- Lower neck load cell bumper

7. Attach a Cable Seat Cover (T1NKM022) to the lower neck load cell using two #2-56 x 3/8" FHSCS {0.050} at both the front and rear neck cable attachment points. These covers are mounted on the front and rear faces of the lower neck load cell bottom plate. **Figure 5.7** shows the location of these cable seat covers.

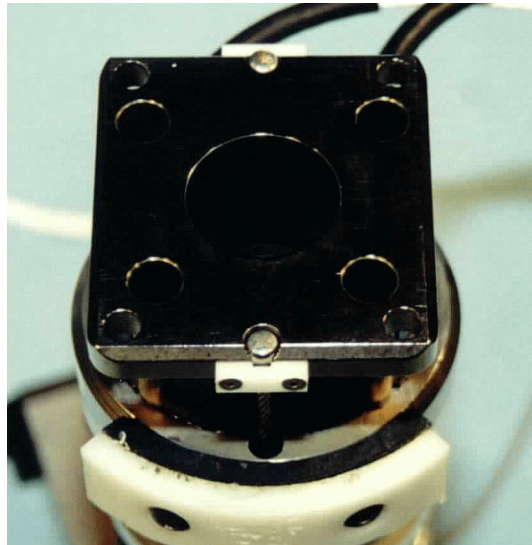


Figure 5.7- Attached cable seat covers

8. Place the Neck Center Cable Fixture (T1NKM120) into the counterbored hole on the Neck Top Plate (T1NKM116). Pass the threaded end of the Neck Center Cable through the center of the Bonded Neck Assembly (T1NKM100) from the top of the neck. Place in the following order on the threaded side of the Neck Center Cable, a Cable Washer (T1NKM029), a flat steel washer, and a nylon spacer (Note: The threaded end of the Neck Center Cable is accessible from the bottom of the lower neck load cell.). Secure the center cable assembly with a 1/4-28 Lock Nut {7/16 socket} by holding the top end of the cable with a flat head screwdriver and tightening the nut 1/2 turn past finger tight. Place the Cable Cover (T1NKM124) on the Neck Top Plate and secure in place using two #2-56 x 1/4" FHSCS {0.050}. The completed assembly is shown in **Figure 5.8**.

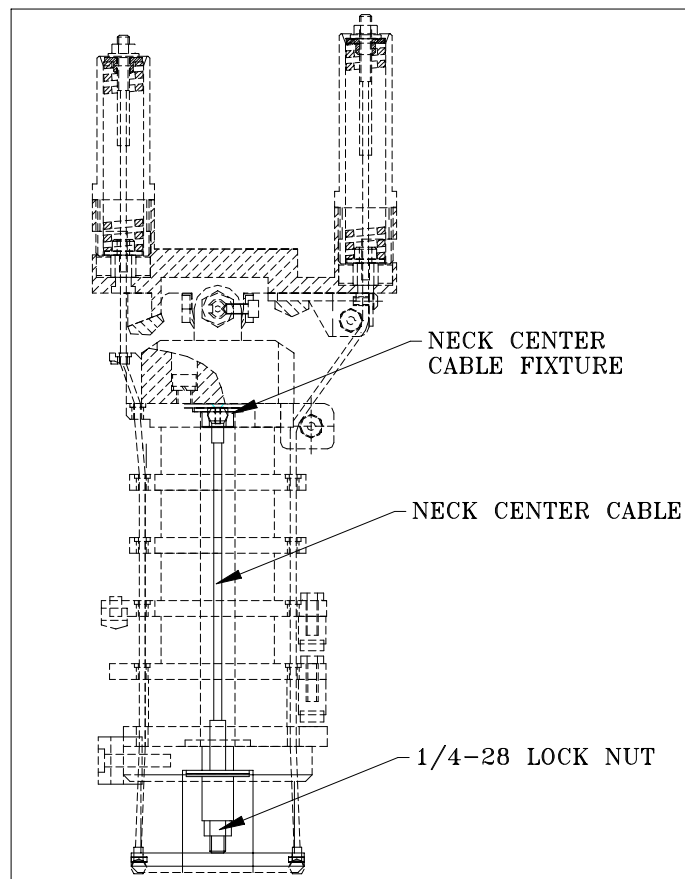


Figure 5.8- Center Cable Assembly

NOTE: During assembly of the Neck Rear Pulley Bracket (T1NKM300), it is important to keep the Rear Neck Cable (T1NKM117) positioned between the Rear Cable Pulley (T1NKM312) and the Neck Top Plate (T1NKM116).

9. Place a Teflon washer on each side of the Rear Cable Pulley (T1NKM312) and position it between the arms of the Rear Pulley Bracket (T1NKM310). Lightly tap the Pulley Shaft (T1NKM311) through the arm bearings, pulley wheel and washers. Center the shaft on the pulley assembly and secure each end of the shaft using a Neck Teflon Washer (T1NKM313), a #4 flat washer, and a #4-40 nylock nut {1/4 socket}. Tighten the nylock nuts until contact is achieved. An exploded view of this assembly is shown in **Figure 5.9**.

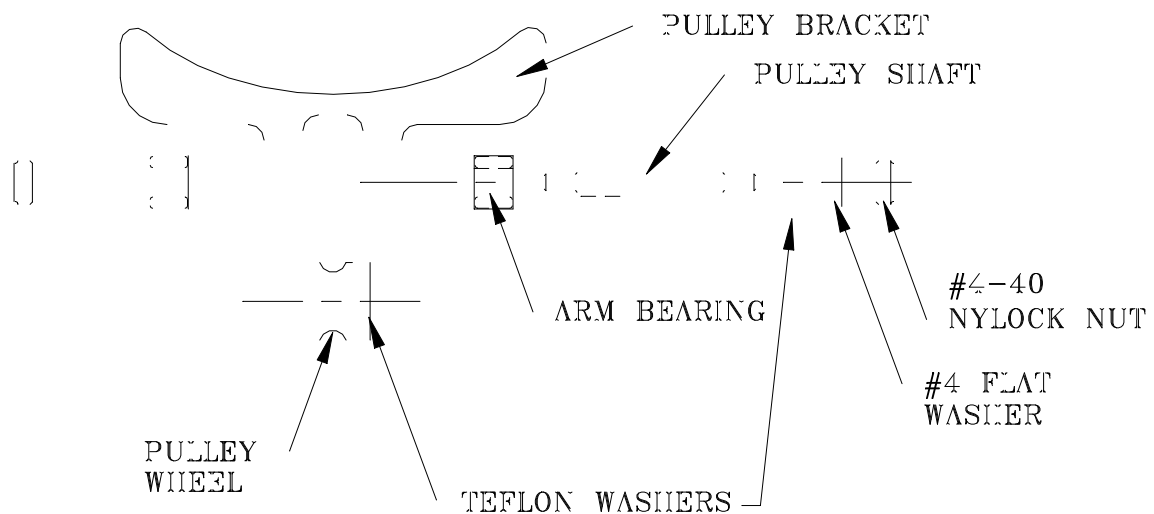


Figure 5.9- Rear cable pulley assembly

10. Install the Upper Neck Load Cell (T1NKM310) to the top plate of the Bonded Neck Assembly (T1NKM100) using four 1/4-20 x 5/8" SHCS {3/16} and four 1/4" split lock washers. Check to be sure that the Occipital Condyle Set Screw (T1NKM027) is in the condyle bolt hole on the Upper Neck Load Cell. **Figure 5.10** shows the attachment of the upper neck load cell.

NOTE: The occipital condyle set screw should not protrude into the center bore for the occipital condyle bolt at this point. It will be tightened once the occipital condyle bolt is in place.

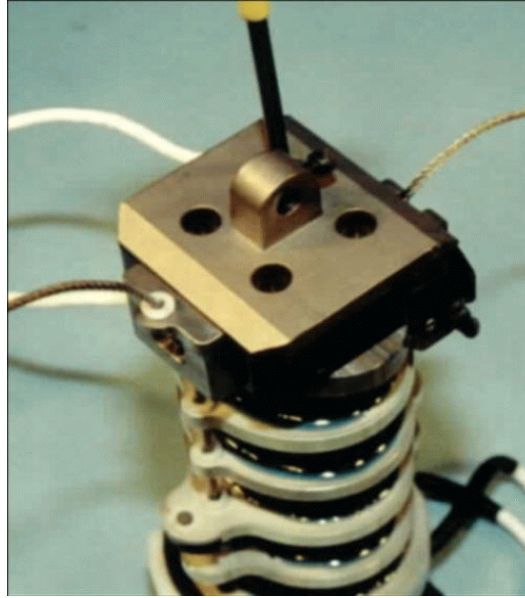


Figure 5.10- Upper load cell attachment

11. Identify the front and rear of the Neck / Head Mounting Platform (T1NKM210) by looking for the pulley assembly on the bottom rear side of the platform. The Neck / Head Mounting Platform is assembled by installing the front and rear Neck Spring Compression Load Cells (T1INM420) into the Neck / Head Mounting Platform (T1NKM210). (Refer to T1NKM200 for further details.) The load cells are slid into position through a slot in the threaded base portion of the Neck / Head Mounting Platform and slid down to rest at the bottom of the front and rear spring bases. The load cell wire is directed out the vertical groove in the spring base section of the Neck / Head Mounting Platform.
12. Tighten the Neck Rear Spring Tube (T1NKM211) into the threaded section of the spring base at the rear of the Neck / Head Mounting Platform (T1NKM210) until the tube makes contact at the necked section above the threads. Repeat this procedure for the Neck Front Spring Tube (T1NKM212) on the front end of the Neck / Head Mounting Platform.
13. Install the Front Neck Die Spring (Blue, 101 lbs/in, 3" Length) into the Neck Front Spring Tube (T1NKM212) with the Delrin Neck Spring Washer Spacer (T1NKM013) toward the top.
14. Install the Rear Neck Die Spring (Yellow, 168 lbs/in, 3.5" Length) into the Neck Rear Spring Tube (T1NKM211) with the Delrin Neck Spring Washer Spacer (T1NKM013) toward the top. **Figure 5.11** shows a drawing of the completed Neck / Head Mounting Platform Assembly.

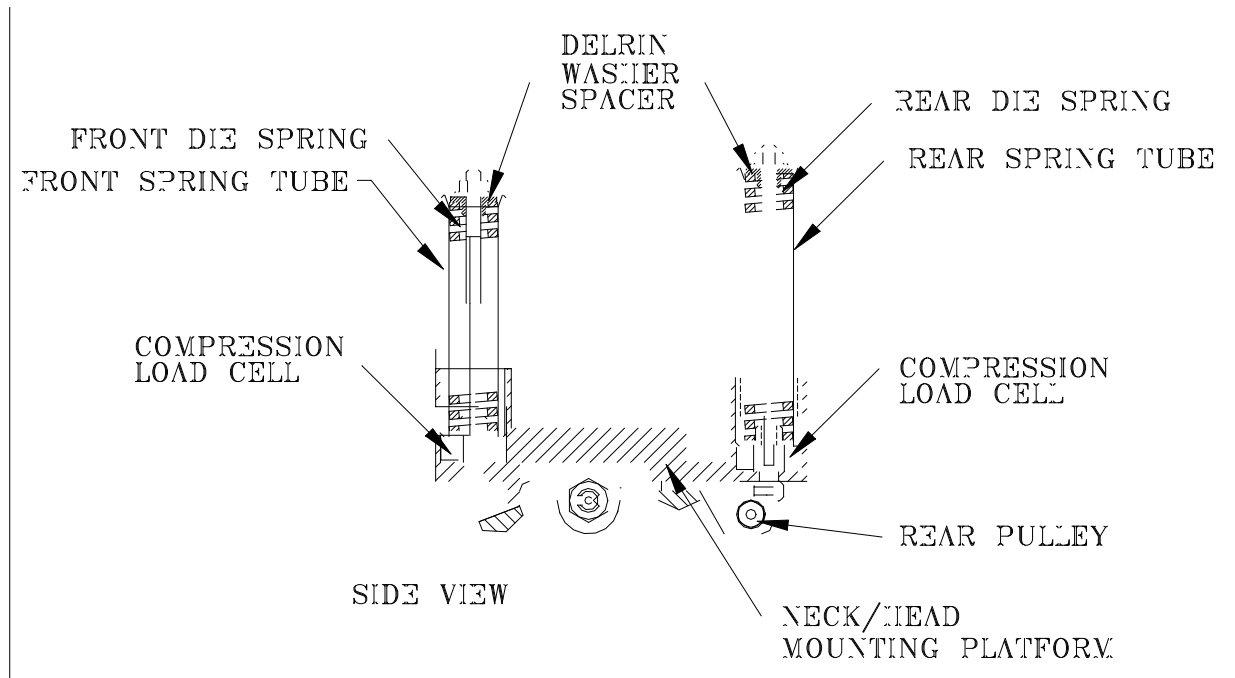


Figure 5.11- Location of springs and load cells

15. Insert four 1/4-28 x 1" BHSCS {5/32} into the mounting holes in the Neck / Head Mounting Platform (T1NKM210) from the bottom side as shown in **Figure 5.12**.

NOTE: A small piece of tape can be used to hold these mounting bolts in place during the rest of the assembly until the neck is ready to mate with the head assembly.

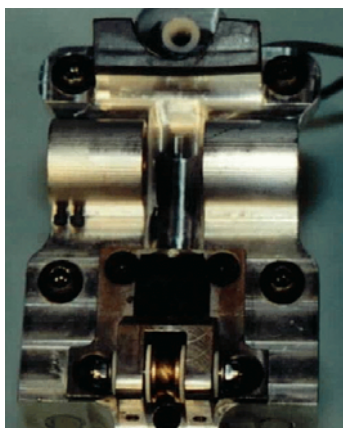


Figure 5.12- Head / Neck mounting bolt locations

16. Pass the threaded end of the front and rear neck cable assemblies up through the front and rear spring tube assemblies in the Neck / Head Mounting Platform (T1NKM210). Secure the cables with a #10-32 Hex Nylon Insert Lock Nut. The adjustment of these nylon insert lock nuts is described in Section 4.3- Adjusting the Head Assembly
17. Prepare the Neck Occipital Condyle Bolt (T1NKM010) by placing hardware on the bolt in the following order: two Curved Disk Spring washers, a Neck Key Washer (T1NKM011), and a Friction Washer (T1NKM012) onto the Condyle bolt as shown in **Figure 5.13**.

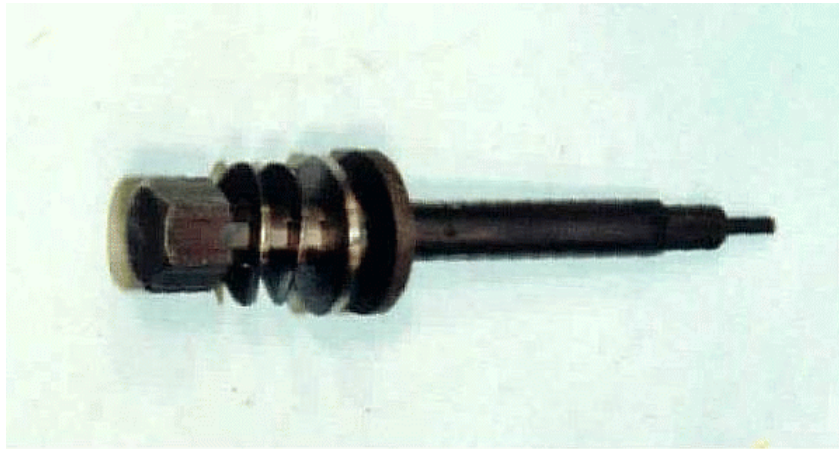


Figure 5.13- Occipital Condyle Bolt assembly

18. Position a 1/4" Brass Washer on each side of the Upper Neck Load Cell condyle mounting area. Install the Neck / Head Mounting Platform (T1NKM210) onto the Upper Neck Load Cell while keeping the brass spacers in place.
19. Pass the Condyle bolt through the Neck / Head Mounting Platform (T1NKM210) and Upper Neck Load Cell from the left side. Secure the Condyle bolt with the following hardware: Friction Washer (T1NKM012), Neck Key Washer (T1NKM011), two Curved Disk Spring washers, a #10 flat washer, and a 1/4-20 nylock nut. Torque the nut to 7 ft-lb. This completed assembly is shown in **Figure 5.14**.

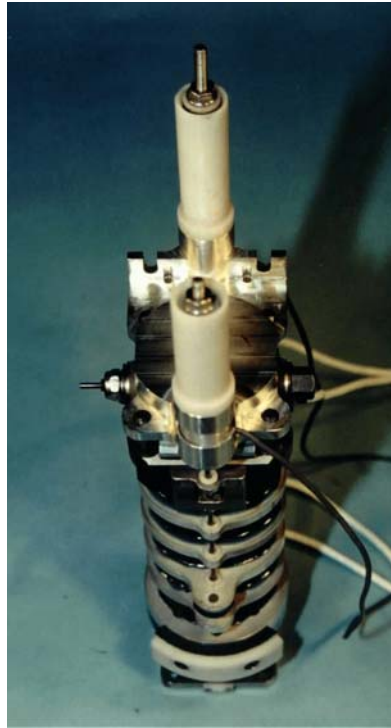


Figure 5.14- Completed assembly to this point

20. Install the Neck Rotary Potentiometer into the Neck Rotary Potentiometer Housing (T1NKM017) by pressing it into place. Align the D-shaped hole in the potentiometer with the flat on the end of the Condyle Bolt and position the potentiometer housing between the Front and Rear Rotary Potentiometer Arms (T1NKM019 & T1NKM020) with the wire and potentiometer terminals pointing down.

WARNING: The d-shaped hole in the potentiometer must be aligned with the flat on the condyle pin or the potentiometer will be permanently damaged.

21. Install the Rotary Potentiometer Housing Cover (T1NKM018) over the neck rotary potentiometer housing with four #0-80 x 1/8" SHCS {0.050}. Secure the rotary potentiometer housing cover to the rotary potentiometer arms using two #2-56 x 1/4" SHCS {5/64}. Secure the rotary potentiometer wire in a 1/8" wire clamp to the rear potentiometer arm using one #6-32 x 3/8" BHSCS {5/64} as shown in **Figure 5.15**.

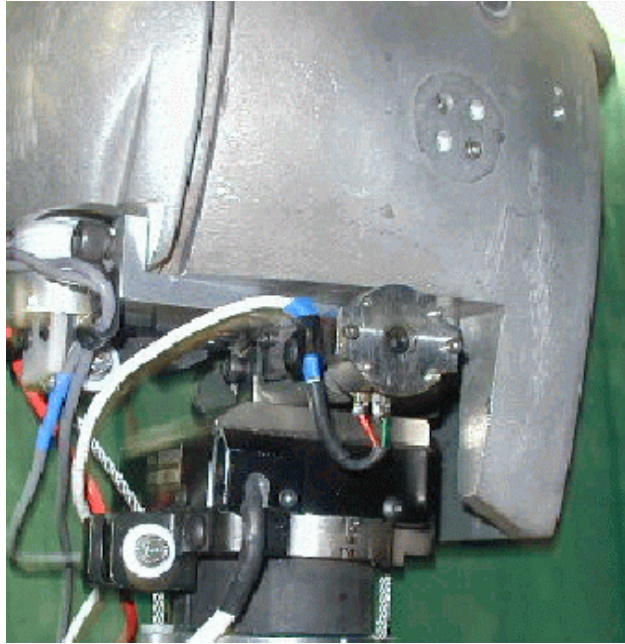


Figure 5.15- Neck potentiometer assembly

5.2.3 Attaching the Neck to the Head

The following procedure is a step-by-step description of the assembly procedure used to attach the head to the neck. The numbers provided in () refer to a specific drawing / part number of each particular part. The numbers noted in { } after the bolt size indicate the size of the hex wrench required to perform that step of the assembly. All bolts should be tightened to the torque specifications provided in Section 2.1.3- Bolt Torque Values.

1. Insert the completed Head / Neck Mounting Platform Assembly (T1NKM200) up through the bottom of the Head Casting Assembly (T1HDM000). Tighten the four 1/4-28 x 1" BHSCS {5/32}. (These mounting screws are typically inserted through the Head / Neck Mounting Platform Assembly (T1NKM200) prior to assembling the condyle bolt - See Section 5.2.2- Step 15 of the Assembly of Neck Components section.

NOTE: The neck must be oriented so that the front cable and spring are positioned toward the front of the dummy. Refer to the neck section for further details.

2. Continue the assembly of the head and neck following the procedure given in Section 4.2.2- Step 7 of the Assembly of Head Components section.

5.2.4 Attaching the Neck to the Spine

The following procedure is a step-by-step description used to attach the lower neck load cell to the top plate of the Neck Pitch Change Mechanism Assembly (T1SPM200). The numbers provided in () refer to a specific drawing / part number of each particular part. The numbers noted in { } after the bolt size indicate the size of the hex wrench required to perform that step of the assembly. All bolts should be tightened to the torque specifications provided in Section 2.1.3- Bolt Torque Values.

1. Pass the Lower Neck Load Cell instrumentation wires and Neck Pitch Change Tilt Sensor wire (T1SPM200) out through the hole at the top of the Upper Thoracic Spine Weldment (T1SPM100) as shown in **Figure 5.16**.

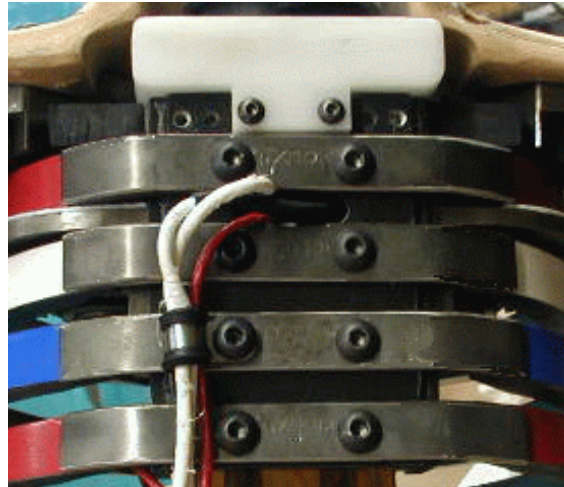


Figure 5.16- Lower neck instrumentation cables

2. Secure the Lower Neck Load Cell to the top plate (T1SPM216) of the Neck Pitch Change Mechanism using four 1/4-20 x 5/8" SHCS- NP {3/16} as shown in **Figure 5.17**.

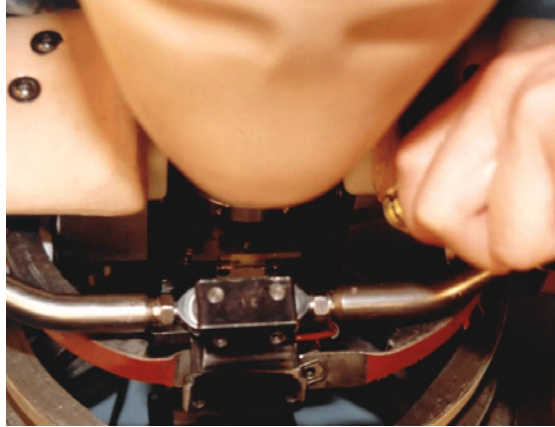


Figure 5.17- Attach the head and neck to the Neck Pitch Change Mechanism

3. Place the Neck Skin (TINKS100) around the Neck Assembly and route the Upper Neck Load Cell wires at the back of the neck along the inside of the Neck Skin. The remaining wires from the head and the neck rotary potentiometer are routed on the outside of the Neck Skin as shown in **Figure 5.18**. Before securing the Neck Skin in place with Velcro, follow step 15 in Section 7.2.2.-Assembling the Thorax, in order to provide the correct amount of slack in the wires.



Figure 5.18- Attaching Neck Skin

5.3 Neck Assembly Adjustments

The following adjustments effect the function of the neck assembly, but are described in other sections where they fit into the procedures described.

Head Angle Adjustment - Described in Section 4.3.1, this adjustment changes the angle of the head relative to the neck assembly - it describes the procedure for properly adjusting the cable tension on the front and rear neck spring assemblies.

Neck Pitch Change Mechanism Adjustment - Described in Section 5.3.2, this adjustment changes the angle of the head and neck assemblies relative to the spine at the approximate anthropomorphic landmark defined by the C7 / T1 joint.

5.4 Electrical Connections and Requirements

The neck has three primary instruments: Upper Neck Load Cell, Lower Neck Load Cell and the Neck Rotary Potentiometer. The instrument wires from the lower neck load cell are routed through the hole in the back of the Upper Thoracic Spine Weldment and secured to the back of the spine using the Wire Covers.

The instrument wires from the upper neck load cell and neck rotary potentiometer are bundled together with the instrumentation wires from the head assembly. This wire bundle is clamped in place along the rear of the spine using the Aluminum Spine Wire Covers. The procedure for this wire routing is described briefly below. For additional details and pictures, refer to Section 7.4- Wire Routing and Electrical Connections for the Thorax Assembly.

NOTE: It is critical to provide the correct amount of slack wire above this clamp to allow the head and neck to move freely in flexion and extension.

1. Holding the wire bundle together, measure 13.5" down the length of the bundle from the bottom of the head mounting plate. Centered at this point, wrap the wire bundle with electrical tape to provide enough thickness to allow the Spine Wire Cover Assembly (T1TXM040) to hold it securely in place. This measurement will create the necessary slack in the wires.
2. Position the taped portion of the bundle under the Spine Wire Cover Assembly and attach above rib assembly #1. This will clamp the wire bundle in position and provide the proper amount of slack in the cable to prevent damage to the instrumentation.
3. The wires from the lower neck load cell and neck tilt sensor is routed out of the hole in the upper thoracic spine weldment (between the mounting points for ribs #1 and #2) and secured to the back of rib #3 using a "C" wire clamp. The wires are then added to the wire bundle running along the back of the spine.

Additional assembly details are provided in Section 7- Thorax Assembly and Section 15- Instrumentation and Wiring.

5.5 Neck Certification

The neck assembly is certified by the Manufacturer using static bending tests and dynamic pendulum tests. The neck is subjected to frontal, rearward, and lateral bending while measuring data for the neck angle, force, and moment. Certification procedures for these tests are described in the THOR Certification Manual which is available from the manufacturer as a separate publication.

5.6 Inspection and Repairs

After a test series has been performed, there are several inspections which may be made to ensure that the dummy integrity has remained intact. Good engineering judgement should be used to determine the frequency of these inspections, however the manufacturer recommends a thorough inspection after twenty tests have been completed. The frequency of the inspections should increase if the tests are particularly severe or if unusual data signals are being recorded. Both electrical and mechanical inspections should be performed. These inspections are most easily carried out during a disassembly of the dummy. The disassembly of the neck components can be performed by simply reversing the assembly procedure.

5.6.1 Electrical Inspections (Instrumentation Check)

This inspection should begin with the visual and tactile inspection of all instrument wires from the neck instrumentation. The wires should be inspected for nicks, cuts, pinch points, and damaged electrical connections which would prevent the signals from being transferred properly to the data acquisition system. The instrument wires should be checked to ensure that they are properly strain relieved. A more detailed check on the individual instruments will be covered in Section 15 - Instrumentation and Wiring.

5.6.2 Mechanical Inspection

Several components in the neck assembly require visual inspection to determine if they are still functioning properly. This mechanical inspection should also involve a quick check for any loose bolts in the main assembly. Areas requiring mechanical inspection are covered in detail below. Please contact the manufacturer with questions regarding parts that fail mechanical inspection.

General: Use the following checklist when inspecting the neck instrumentation for post-test damage:

- C Check the tightness of all instrumentation mounting bolts

Cables: Use the following checklist when inspecting the neck cables for post-test damage:

- C Check the tightness of the center neck cable - Section 5.2.2 - Step 8.
- C Inspect the front, rear and center cable assemblies for signs of fraying, broken strands, and kinking

Adjustments: Use the following checklist when inspecting the neck adjustments during post-test inspection:

- C Check the head angle adjustment, including cable tension adjustments - Section 4.3.1

Bonded Neck

Assembly: Use the following checklist when inspecting the neck for post-test damage:

- C Mechanically inspect the neck assembly for signs of debonding between the aluminum disks and the rubber pucks - particularly along the first two pucks at the rear of the neck
- C Inspect the front and rear neck soft stop assemblies for signs of debonding or permanent compression

Neck Skin: Use the following checklist when inspecting the neck skin for post test damage:

- C Check the Neck Skin for tears or holes, especially in areas where the shoulder belt could make contact